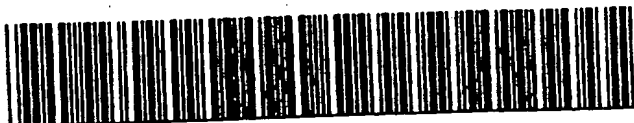


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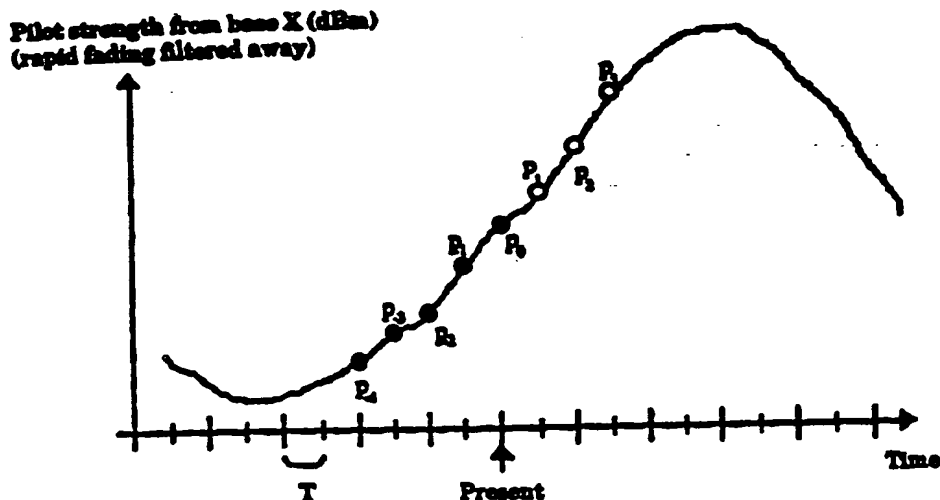
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(54) Title: METHOD AND DEVICE AT CELLULAR TELECOMMUNICATION SYSTEM



(57) Abstract

In a cellular telecommunication system one and the same mobile unit can be connected to two or more base stations, which implies that the system operates with macro diversity. Respective concerned mobile unit operates with an active set-function or a connection pattern which indicates and estimates the mobile unit's connection situation in relation to concerned base stations, and decides about changes in the connection situation. In the system the mentioned active set is predicted adaptively by means of previously obtained data or parameters. By the invention are achieved improved system functions at which can be mentioned safe handover-function, better transmission quality in the border areas of the cells, etc.

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**TITLE OF THE INVENTION**

Method and device at cellular telecommunication system.

5

**TECHNICAL FIELD**

The present invention relates to a method at cellular telecommunication system where respective concerned  
10 mobile unit at the same time can be connected to two or more base stations, i.e. the system operates with macro diversity. Further, respective concerned mobile unit shall operate with an active set or connection pattern which indicates and estimates the connection situation  
15 of the mobile unit in each moment in relation to the base stations concerned, and decides about changes in the mentioned connection situation. The invention also relates to a device at cellular telecommunication system of the by way of introduction mentioned kind.

20

**STATE OF THE TECHNOLOGY**

By the PCT-application WO 91/17608 is described a method  
25 to predict future measurement values for handoff-decisions. According to the application, measurements are performed of for instance the signal strenght on a transmission. To make possible to make handoff-decisions at an early stage, a prediction of the signal  
30 strength is performed at a later point of time. At this an adaptive filter is used. According to the application the mobile can perform measurements on surrounding base stations or vice versa.

35 By the American patent 4 556 760 can in a cellular mobile telephone system a handoff- filter be used. The

patent describes a filter function which is usable for evaluating for instance amplitude variations at a mobile unit which is moving in the neighbourhood of a cell border.

5

The filter function offers both long and short averaging of received signal. These averages can be used together with the latest measured value to predict future values.

- 10 The American patent 5 267 261 describes a mobile assisted "soft" handoff in a cellular communication system using CDMA. The described method, which is also called base station diversity, implies that communication between mobiles can be made over a number  
15 of base stations at the same time. Maintaining of active setting is included in the method. Nothing, however, is mentioned about prediction.

- By the PCT-application WO 92/12602 is indicated how  
20 handover at mobile radio system is to be performed. The mobile unit measures the strength of signals from surrounding base stations, and bases the handover decision on the basis of increase or decrease of the mentioned signal strengths.

25

- The European patent application 462 952 describes adjustment of output in a digital mobile telephone system. The invention is intended to keep the transmitted power on optimal level, i.e low enough not  
30 to disturb, but high enough to be possible to be received at the receiver. The adjustment decision is based on predicted future signal strenght values which in their turn are calculated on previously measured values, for instance signal strength, signal quality,  
35 which are averaged.

By the American patent 5 203 010 is shown a cellular radio telephone system. In this the base station measures the signal strenght of the signal from the mobile unit and calculates a future value which it then  
5 communicate to surrounding base stations.

## DESCRIPTION OF THE INVENTION

### 10 TECHNICAL PROBLEM

In CDMA-systems it is comparatively easy to implement macro diversity. Therefore this exists as a natural part in Qualcoms CDMA-system and in the CODIT-project's (RACE  
15 II) system concept and test system. By macro diversity is in this connection meant that a mobile can be connected to more than one base at the same time to keep up a connection. In order to use as much as possible of total received payload signal (from different base  
20 stations in the downlink, in the uplink a number of base stations receive the same signal) are then different combination methods used both on mobile- and network side. Normally, if macro diversity is used, a mobile in the border area of a cell is always connected to more  
25 than one base. In this way is, among other things, a more secure handover obtained, so called soft handovers, higher quality of transmission in border areas and generally more secure connections in border areas.

30 A central concept in the connection is "the mobile station active set". The mobile's active set defines which base stations the mobile at present are connected to. The function "the active set update function" evaluates continuously the mobile's active set and  
35 decides about connections and disconnections, if any, i.e. all changes of the mobile's active set. The

decisions are based on pilot measurements (each base station has a unique pilot channel with known, often constant and equal output). Which algorithm that is used for deciding about changes of the mobile's active set is  
5 unimportant in the connection, as long as the evaluation is based on the pilot measurements.

In principle one is aiming at keeping the strongest base stations in the mobile's active set. Strongest implies  
10 in this connection those bases which experience the smallest attenuation (the sum of the distance attenuation and the slow fading, rapid fading is filtered away). In this way power is saved and by that capacity. Consequently optimally a mobile in macro  
15 diversity only uses the links which at present have the smallest propagation losses (the rapid fading disregarded).

To achieve the above, the mobile detects and measures  
20 continuously the strongest pilots. The rapid fading is filtered away, in CODIT median filters are used for this, the values are after that collected to a measurement report. Measurement reports are sent at a certain pace to system management, where the mobile's  
25 active set is evaluated (thus the report goes to the active set update function). In CODIT a second filtering is made before the measurement values are used, but how the filtering is managed is unimportant for the invention. The problem is that measurement values which  
30 are used for the evaluation of the mobile's active set are "old", the total time between measurement point of time and point of time for a resulting change of the mobile's active set can be 1-2 seconds or more. This is due to delays in the measurement process itself, in the  
35 filtering, in the reporting and in delays at signalling

and transmission of data, and in the connection of a new base (synchronization).

The delay brings about increased interference level,  
5 bigger variation of received signal/noise relation (i.e lower quality) and increased power consumption.  
Generally can be said that a CDMA-system with macro diversity (and power adjustment in up- and downlink) is comparatively sensible to delays of this kind. Optimally  
10 would be to know the pilot strengths in the future, during the time that an active set shall be valid. This is also in principle what the invention is aiming at. Even if the description here is based on a CDMA-system with macro diversity based on pilot strenght  
15 measurements, the formulation of the problem is more general. The problem exists in all mobile systems with macro diversity (according to the definition which has been made here), where the macro diversity is controlled by means of measurements which are correlated with the  
20 sum of the distance attenuation and the long fading between base and mobile. (These two quantities are in the general case much correlated in up- and downlink). It is assumed that it is not possible to design a system without delays.

25

#### THE SOLUTION

What can in the main be regarded as significant for the new method and device will be apparent from the  
30 following patent claims.

#### DESCRIPTION OF FIGURES

The invention will be described in the following while  
35 at the same time references are made to enclosed drawings where:

Figure 1 in curve form shows pilot strength after filtering away of rapid fading, at which measurement values and future measurement values are indicated on the curve, and T represents a measurement reporting period.

Figure 2 in the form of block diagram shows an adaptive active connection prediction where the memory processing is not shown but central processing of the measurement values are assumed, at which the system is digital/discrete and is shifted at the same pace as the measurement values arrive, and measured pilot strength is the value after filtering away of rapid fading.

15

#### DETAILED DESCRIPTION

The invention is based on the fact that the slow fading is predictable, at least during the time intervals, i.e. one or a few seconds, which is of interest here. The same also applies in principle to the distance attenuation during the mentioned time interval. This because the pattern of movement of a vehicle does not change instantaneously, a car does not turn 180° at 70 km/hour. A walking user, on the other hand, is not possible to predict, but in this case the distance attenuation is neither considerably changed during studied time interval. Thus, instead of basing the evaluation of the mobile's active set on the latest batch of received measurement values (after filtering), i.e. only on the information in the latest received measurement report, previously received reports are also used to estimate the situation in an immediate future (i.e. one or a few seconds later). Two fundamental strategies are suggested, see Figure 1, for the strongest pilots:



A. Predict the pilot strength one or more periods of time (i.e. measurement reporting periods, in the interval 0,25 - 2,0 seconds) ahead in time. Base the evaluation on these predicted values. Thus  
5 make use of available measurement values  $p_0$  up to and including  $p_{-k}$ ,  $k > 0$ , for predicting  $p_1$ ,  $l=1,2$ . Use a one step- or multistep predictor. At multistep prediction either a true multistep predictor can be realised, or a one step predictor  
10 which is iterated can be used. More about predictors follows.

B. Predict the time average of the pilot strength a number of time periods ahead in the time. Base the  
15 evaluation on these predicted values. Two variants are possible, to predict separate pilot strength values and calculate the time average, or to predict the time average directly. Accordingly use available measurement values  $p_0$  up to and  
20 including  $p_{-k}$ ,  $k > 0$ , for predicting for instance  $p_1/2 + p_2/2 + p_3/2)/T$ , where  $T$  is the reporting period which is known.

Both methods thus require one (the case in strategy A  
25 and possible in strategy B) or more predictors (can be the case in strategy B) per pilot which is detected in the mobile. This calls for memory capacity and calculating capacity. This should not cause any problems in the future generations of mobile systems. Possible  
30 predictors follow. Furthermore are needed functions to secure the stability, which will also be touched upon. Finally are needed functions for automatic connection and disconnection of the predictors, which will also be discussed. The latter are needed because it is probably  
35 pointless (with the time interval and the measurement

reporting periods which are discussed here) to predict in indoor environment.

Three possible embodiments of predictors are suggested:

5

1. If one restrict oneself to linear predictors, an RLS-predictor (Recursive Least Squares) is the best choice. RLS-predictors are possible to analyse (will however take some time in the general case) and are comparatively easy to implement. We skip the mathematical description here and establish that there exist robust methods with reasonable calculation - and memory consumption. By using an RLS-algorithm one can obtain BLUE (Best Linear Unbiased Estimation). Consequently it is not possible to construct a better linear average true predictor with lower fault variance (the fault is the difference between predicted and real value). There may however be (there are in most cases) predictors which are not linear or not average true with lower variance on the fault.

15

20

25

30

2. A more sophisticated method is to use a neural network as predictor. Neural predictors are considerably more difficult to analyse (a complete analysis on a larger predictor can be an impossibility, which can be proved). In any case good results can be obtained even if the preparations are considerably more extensive. It is in most cases possible to get compact and robust, not necessarily linear or average true, predictors by using neural networks. The field is a science in itself.

35

3. A third method which is neither quite uncomplicated, is to use an ML-predictor (Maximum

Likelihood). The method is based on that the measurement values comes from distributions which are at least partly known, which definitely is the case here. The slow fading is approximatively  
5 lognormal, the measurement faults are possible to estimate and the distance attenuation is dependent on the movement pattern of the mobile. As the movement pattern is possible to analyze, an approximative distribution can be obtained. It can  
10 be shown that ML-predictors which are linear (which is not a demand) can reach BLUE.

There is always a small risk that a predictor becomes instable during one or a few samples. Different  
15 predictors are more or less robust, often depending on how it is implemented even if the same mathematical algorithm is used. Beside building in stabilisation criteria in the predictor itself, which requires comparatively much additional work, there are always  
20 parameters which control the inertia in the adaption process. A correct balance often gives a very stable solution. A completing method, to secure the stability, which is suggested here is to use the knowledge about the measurement signal:

25  
- Measure continuously the difference between two consecutive measurement values,  $\Delta_m$ , with a gliding window. Decide  $\Delta_t$ , so that  $P(|\Delta_m| < \Delta_t) = 95\%$  (for instance) within the interval, i.e the probability that  $|\Delta_m|$  is  
30 below  $\Delta_t$  is 95% within the interval. A more simple variant is of course to use a fixed  $\Delta_t$ , the value of which is decided by previous measurements and considering the measurement report period.

35  
- Measure continuously the difference between two consecutive predicted values,  $\Delta_p$ , If  $|\Delta_p|$  exceeds  $\Delta_t$ ,

then restrict the output value, i.e. the predicted value, from the predictor so this is not the case any longer.

- 5 The method has for almost obvious reasons a very stabilizing effect, especially at multistep prediction where one iterates up a one step predictor. If the threshold value is not set too low, the goodness of the predictor will not be influenced of any note. This  
10 method can be used at initial simulations.

When predictors are used it is always possible to check the goodness in previous predictions. This by comparing previous predicted values with measurement values. This  
15 gives an opportunity to disconnect the predictor if the prediction faults become too large. In certain surroundings it can be difficult to predict future values, in these cases it is better to disconnect the predictor and use the measurement values directly.

20

A simple method is to continuously compare with the fault in an imagined predictor which uses the latest measurement value as a predicted value (in other words no prediction at all). If the prediction faults at a  
25 mobile thus are too large, according to the above, during a certain time period, the predictors will be coupled by, and and the measurements values will be used directly.

30 When the fault rate decreases, the predicted values will be used again. The analogy with selection diversity is not altogether misleading. This method is not used at initial simulations.

35 The foundation stones of the invention are the predictor, the stability control and the efficiency

control, schematically connected in Figure 2. Before this there is the measurement process itself and the filtering for elimination of rapid fading. After there is the evaluation routine which decides if, and in that case how, the mobile's active set shall be changed. A known evaluation routine which is produced within CODIT exists. A similar routine is used in Qualcomm's system.

The invention can be used in mobile CDMA-system with macro diversity with the meaning which is indicated here. The invention can be directly realised in the CODIT system. More generally the product can be used in the mobile systems of the third generation, if the macro diversity is implemented and suitable measurement channel is available (shall be correlated to the slow fading on up- and downlink and of course the distance attenuation). Demands are also made on the measurement intensity, calculation- and memory capacity. There is, however, no demand that the measurements shall be performed at the mobile even if this will simplify the use. The invention is possible to implement by means of measurements on the network side instead. The invention is usable in systems where an increased importance is attached to, by means of measurements and measurement value processing, increase the capacity and the transmission quality.

The different parts individually, possibly with exception of the efficiency control, are built on in itself known technology. The total system and the field of use is however new. Known alternative methods (CODIT and Qualcomm) are low pass filtering of the measurement values. The interference level can be lowered in both up- and downlink, and the quality of up- respective downlink can be increased. The gains are expected to be higher after a more exakt design, trimming and analysis.

The invention is used foremost in mobile CDMA radio systems and might also be used in modern TDMA-system, for instance of the type DECT. The invention can also be used for the mobile radio systems of the third  
5 generation, compare UMTS/FPLMTS which probably will be CDMA-based. By the invention is achieved higher quality of the radio transmission, higher capacity, a smaller number of base stations, which in its turn leads to cheaper installation, more satisfied users, which in its  
10 turn give obvious competition advantages.

## PATENT CLAIMS

1. Method at cellular telecommunication system where  
respective concerned mobile unit at the same time can be  
5 connected to two or more base stations, i.e. the system  
operates with macro diversity, and respective concerned  
mobile unit operates with an active connection function  
or active set function which indicates and estimates the  
connection situation of the mobile unit in relation to  
10 concerned base stations and decides about changes in the  
connection situation, c h a r a c t e r i z e d in that  
in the system the connection situation/active set is  
adaptively predicted by means of previously obtained  
data or parameters with the aim to make improved system  
15 functions, for instance more secure hand-over function,  
better transmission quality in the border areas of the  
cells etc.

2. Device at cellular telecommunication system where  
20 respective concerned mobile units at the same time can  
be connected to two or more base stations, i.e. the  
system operates with macro diversity, and respective  
concerned mobile unit operates with an active connection  
function/active set function which indicates and  
25 estimates the connection situation of the mobile unit in  
relation to concerned base stations and decides about  
changes in the connection situation,  
c h a r a c t e r i z e d in that the system is arranged  
to, depending on previously received data or parameters,  
30 make adaptive prediction of the connection  
situation/active set with the aim of getting improved  
system functions, for instance more secure hand-over  
function, better transmission quality in the border  
areas of the cells etc.

3. Device according to patent claim 2,  
c h a r a c t e r i z e d in that the prediction is  
performed one or a few seconds ahead in the time and is  
based on data or parameters with comparatively long  
5 backward holding from the view of point of time.

4. Device according to patent claim 2 or 3,  
c h a r a c t e r i z e d in that the pilot strength is  
predicted one or more time periods in an interval  
10 between 0,25- 2,0 seconds ahead in the time, and that  
evaluation will be based on these predicted values, at  
which available measurements values  $p_0$  up to and  
including  $p_{-k}$ , where  $k > 0$ , for predicting  $p_1$ , where  
 $l=1,2$ .

15 5. Device according to any of the patent claims 2-4,  
c h a r a c t e r i z e d in that a one step- or a  
multistep predictor is included, at which in the case  
with multistep predictor a true multistep predictor is  
20 included, or in the case with a one step predictor this  
is iterated.

6. Device according to any of the patent claims 2-5,  
c h a r a c t e r i z e d in that the time average of  
25 the pilot strength will be predicted a number of time  
periods ahead in the time, after which the evaluation is  
based on these predicted values, at which in a first  
case separate pilot strength values are predicted and  
the time average is calculated in dependence of this  
30 prediction, or the time average is directly predicted,  
at which consequently measurement values  $p_0$  up to and  
including  $p_{-k}$  where  $k > 0$  can be used, for instance to  
predict  $(p_1/2+p_2+p_3/2)/T$ , where  $T$  is the known report  
period.

35



7. Device according to any of the patent claims 2-6,  
c h a r a c t e r i z e d in that one or more predictors  
per pilot is used and that detection is performed in the  
mobile, at which memory capacity and calculation  
5 capacity is included.

8. Device according to any of the patent claims 2-7,  
c h a r a c t e r i z e d in that functions for securing  
of the stability are included, and that devices are  
10 arranged for automatic connection and disconnection of  
the predictors.

9. Device according to any of the previous patent claims  
c h a r a c t e r i z e d in that linear predictors are  
15 included, at which respective linear predictor can  
consist of an RLS-predictor which operates with an RLS-  
algorithm.

10. Device according to any of the patent claims 2-9,  
20 c h a r a c t e r i z e d in that as predictor is used a  
neural network.

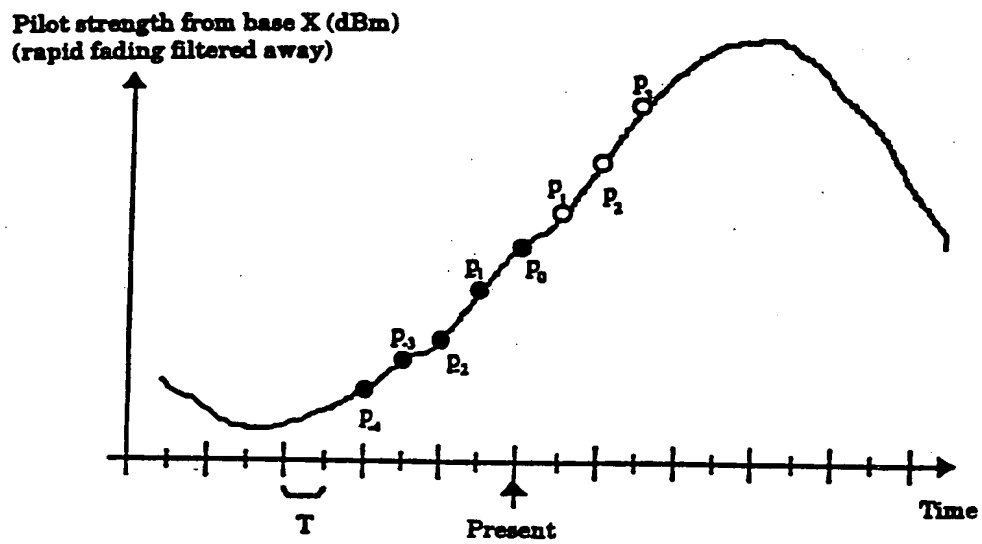
11. Device according to any of the patent claims 2-10,  
c h a r a c t e r i z e d in that an ML-predictor is  
25 used which operates with measurement values which come  
from or are obtained from distributions which are at  
least partly known.

12. Device according to any of the patent claims 2-11,  
30 c h a r a c t e r i z e d in that the predictor is  
arranged with stability criteria, or that parameters  
which control the inertia in the adaption process are  
included, at which securing of the stability can use the  
knowledge about the measurement signal, and the  
35 difference between two consecutive measurement values is  
measured continuously with a gliding window, or that the

difference is measured continuously between two consecutive predicted values.

13. Device according to any of the patent claims 2-12,  
5 c h a r a c t e r i z e d in that the goodness in the previous predictions are controllable by for instance comparison of previously predicted values with measurement values, which makes possible for instance that the predictor can be disconnected if the prediction  
10 faults become too large, or that the fault in an assumed predictor which uses the latest measurement value as a predicted value is continuously compared.

14. Device according to any of the patent claims 2-13,  
15 c h a r a c t e r i z e d in that central memory processing is included in connection to predictor, efficiency control and stability control.

**Fig 1**

**Fig 2**